Update on DVCS

S. Fazio

EIC Task Force meeting

BNL – July 21, 2011

MILOU

Written by E. Perez, L Schoeffel, L. Favart [arXiv:hep-ph/0411389v1]

The code MILOU is Based on a GPDs convolution model by:
A. Freund and M. McDermott [All ref.s in: http://durpdg.dur.ac.uk/hepdata/dvcs.html]

- ✓GPDs, evolved at NLO by an indipendent code which provides tables of CFF
  - at LO, the CFFs are just a convolution of GPDs:

$$\mathcal{H}(\xi,Q^2,t) = \sum_{\mathrm{u,d,s}} \int_{-1}^{1} \left[\frac{e_i^2}{1 - x/\xi - i\varepsilon} \pm \{\xi \to -\xi\} \right] H_i\left(x,\xi,Q^2,t\right) dx$$

- ✓provide the real and imaginary parts of Compton form factors (CFFs), used to calculate cross sections for DVCS and DVCS-BH interference.

$$\frac{d\sigma}{dxdyd\,|t|\,d\phi d\varphi} = \frac{\alpha^3 x_B y}{16\pi^2 Q^2 \sqrt{1+\varepsilon^2}} \left| \frac{\mathcal{I}}{e^3} \right|$$

$$\phi = \phi_N - \phi_l$$

$$\varphi = \Phi_T - \phi_N$$

$$\varepsilon \equiv 2x \frac{m_N}{Q}$$

$$|\mathcal{I}_{BH}|^2 = \frac{e^6}{x^2 y^2 (1+\varepsilon^2)^2 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{BH} + \sum_{n=1}^{2} c_n^{BH} \cos(n\phi) + s_1^{BH} \sin(\phi) \right\}$$

$$|\mathcal{I}_{DVCS}|^2 = \frac{e^6}{y^2 Q^2} \left\{ c_0^{DVCS} + \sum_{n=1}^{2} \left[c_n^{DVCS} \cos(n\phi) + s_n^{DVCS} \sin(n\phi) \right] \right\}$$

$$|\mathcal{I}|^2 = \frac{\pm e^6}{x y^3 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{I} + \sum_{n=1}^{3} c_n^{I} \cos(n\phi) + s_1^{I} \sin(\phi) \right\}$$

- ✓ $\frac{d\sigma}{d|t|} = \exp\left(B\left(Q^2\right)t\right)$ -> The B slope is allowed to be costant or to vary with Q^2:
- ✓Proton dissociation ($ep \to e\,\gamma\,Y$) can be included
- ✓Other non-GPD based models are implemented like FFS, DD

new version of MILOU now on on AFS.
Instructions on the code and its output files are on the wiki page:
https://wiki.bnl.gov/eic/index.php/MILOU

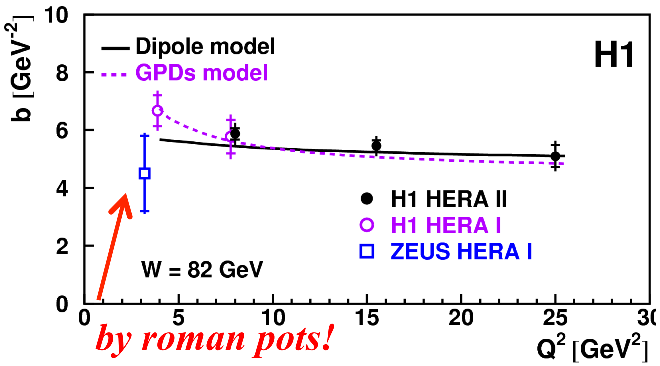
List of improvements a.r.o. the original version:

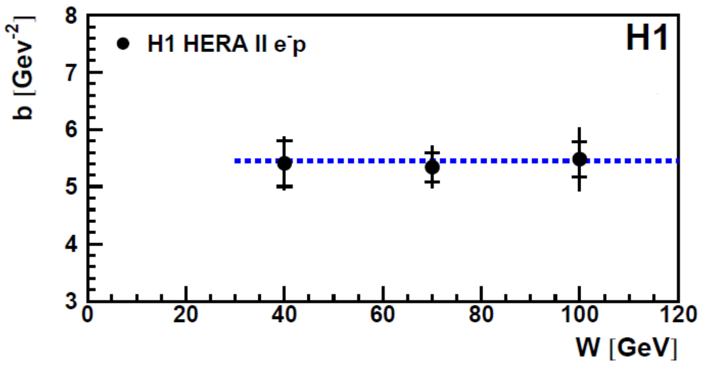
1) **Fixed the FORTRAN common blokes:** they where rewritten by bases and did not preserve the random seed as set in the cards. That caused one had to recalculate the integral every generation (which take days). Now the integral can be calculated ones per energy conf. and the same grid used for each generation.

2) **Corrected ALLM parameterization for F2 implemented (relevant when running in FFS-model mode)**. this caused a disagreement between the GPD and the FFSs models of a factor two or more in the cross sections even at HERA energies. The correct ALLM is taken from the original ALLM paper hep-ph/9712415v2, so the agreement between the two models at HERA energies and with the predictions from the GenDVCS Monte Carlo (also using FFS and used by the ZEUS Collaboration) it is now satisfactory.

3) **The output is not not only in the form of a PAW ntuple but the code creates a text file in the Pythia-like ascii format**, in the same standard of other MCs for EIC. Output description is on the web-page.

Scanning the phase space…





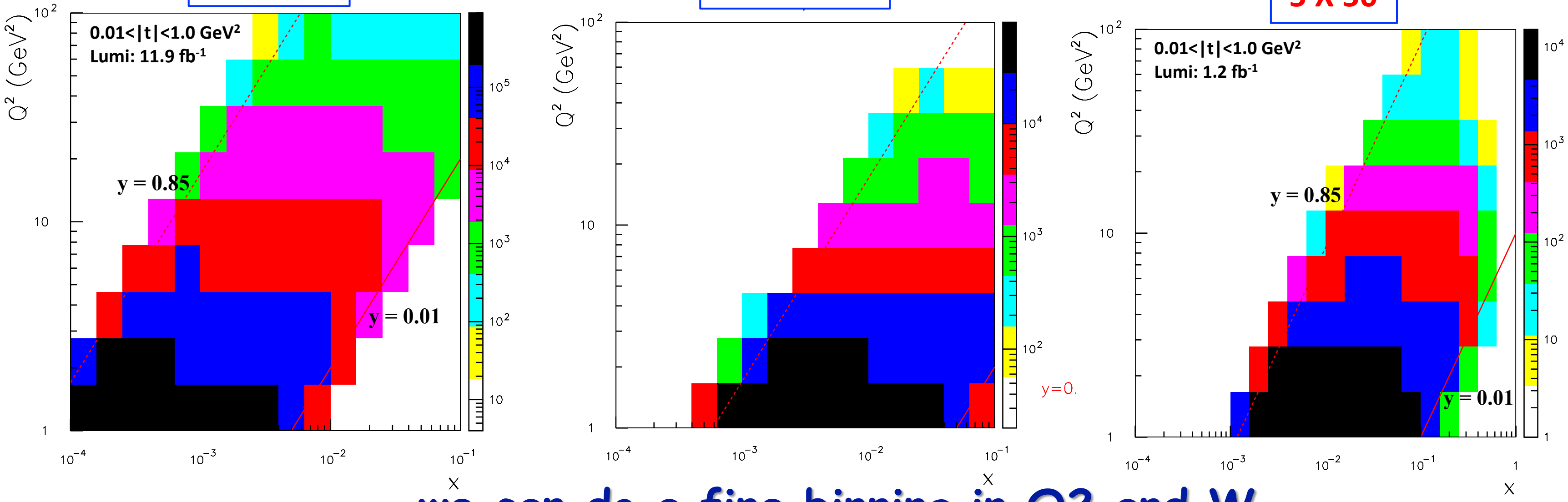
EIC lumi:
11.6 fb^{-1}/month @ 20x250

- **EIC will provide sufficient luminosity to bin in multi-dimensions**
- **wide x and Q^2 range needed to extract GPDs**

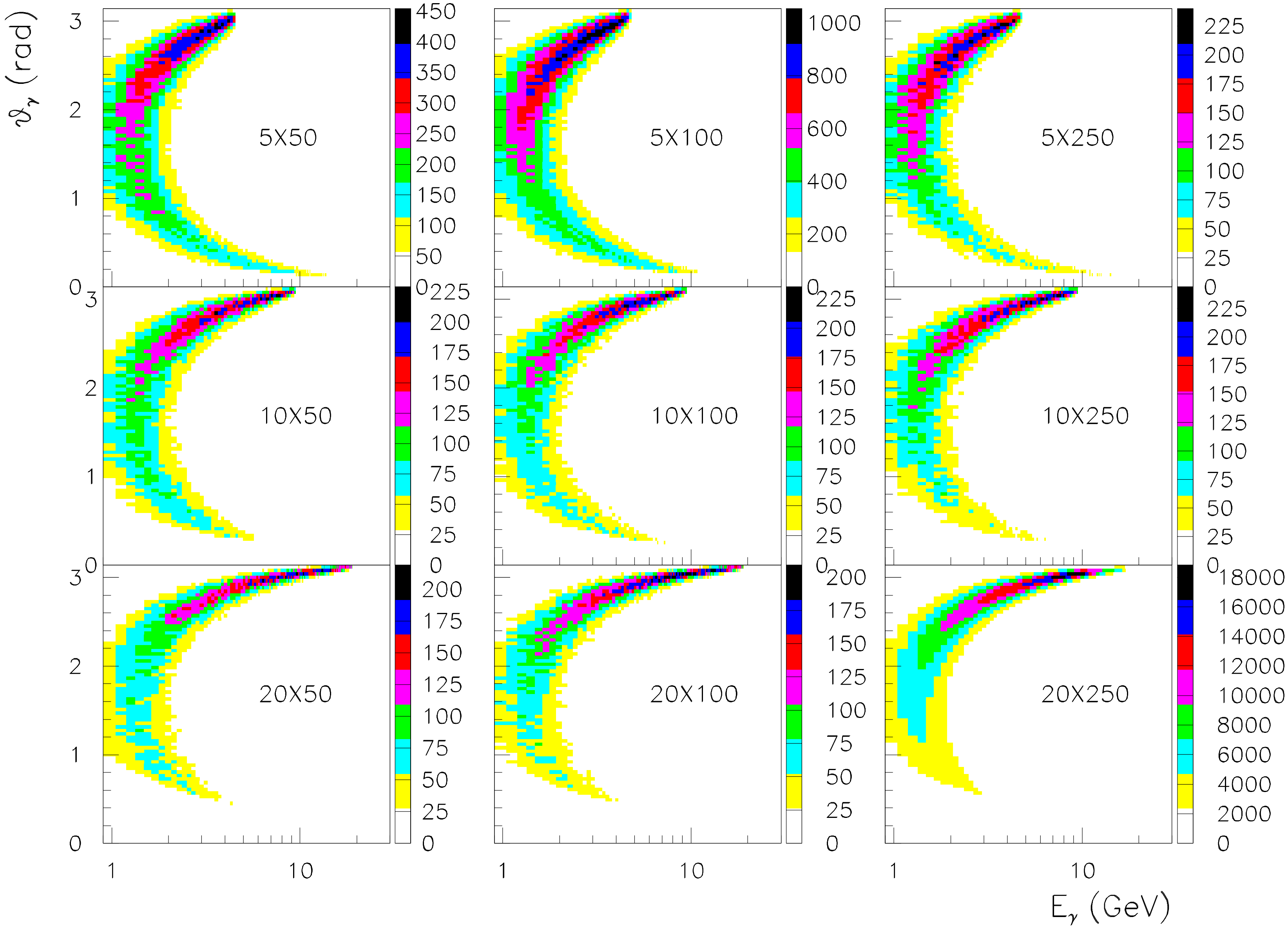
Logarithmic bins: $1 < Q^2 < 100$ GeV^2

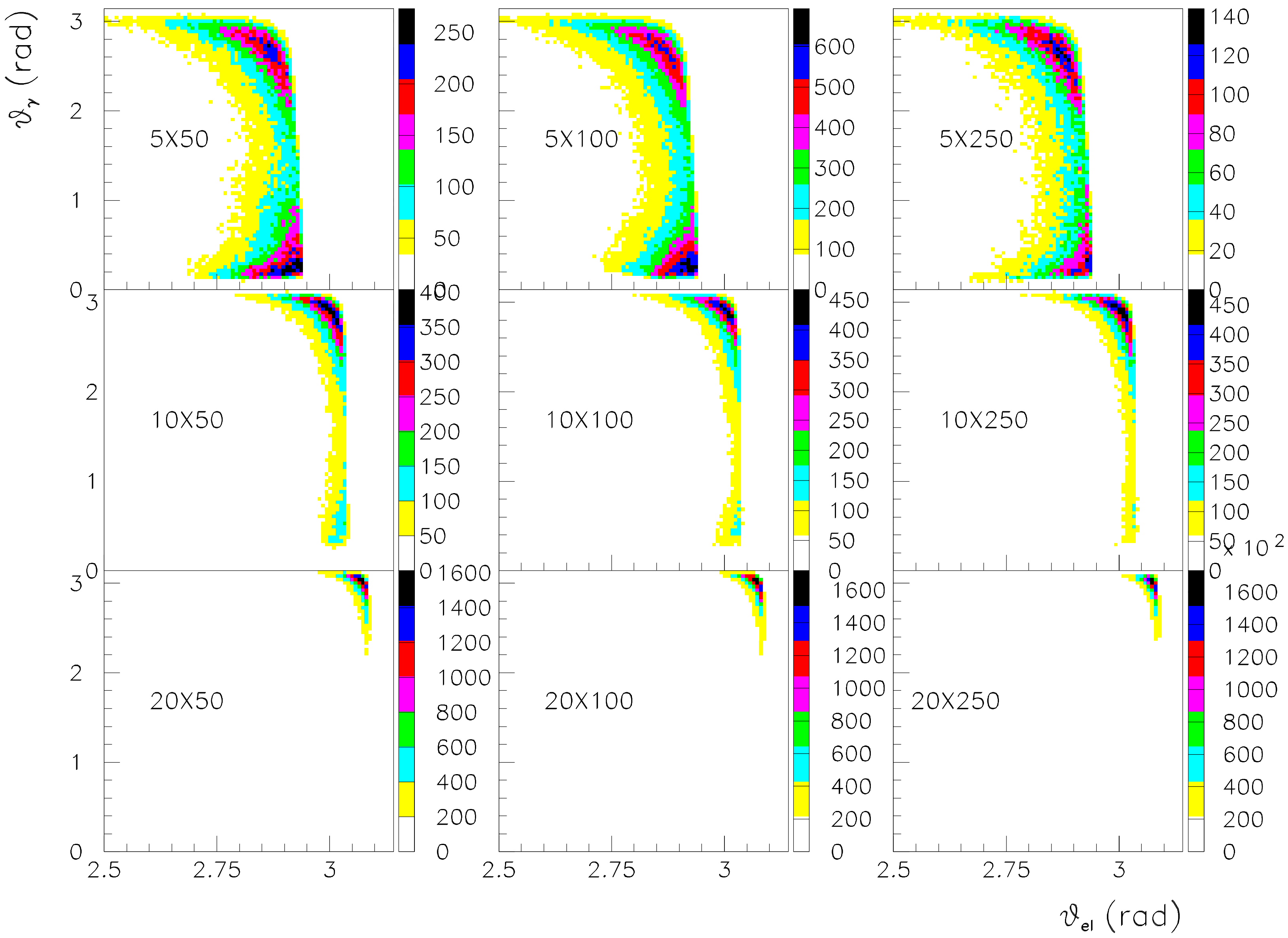
$10^{-4} < x < 0.1$

20 X 250 **5 X 100** **5 X 50**



… we can do a fine binning in Q2 and W


ϑ_γ (rad)
5X50
5X100
5X250
10X50
10X100
10X250
20X50
20X100
20X250
E_γ (GeV)



ϑγ (rad)
ϑel (rad)
5X50
5X100
5X250
10X50
10X100
10X250
20X50
20X100
20X250
x 10 2

|t|-differential cross section

$0.01 < |t| < 1.0$ GeV^2

- Precision enormously improved a.r.o. present (mostly below 1%)
- Systematics will dominate!
- Mostly within Roman pots acceptance ($|t|>0.06$ GeV^2),

i.e. RP @ ZEUS:
Resolution LPS: Pt=5 MeV -> $|t|=10^{-2}$Pt

$1.0 < |t| < 2.0$ GeV^2

- Xsec drops drastically
- eRHIC still allows for good binned measurements after years of data taking
- Main detector can be used for measuring |t| from momentum conservation.

DVCS: the beam-charge asymmetry

$$|A|^2 = |A_{DVCS}|^2 + |A_{BH}|^2 + |A_I|^2$$

DVCS and BH: identical final state → they Interfere

Interference term: $A_I \propto Re(A_{DVCS}) + Im(A_{DVCS})$

$|A_{BH}|$ is well known

Beam charge asymmetry:

$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\mathrm{Re}\, A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

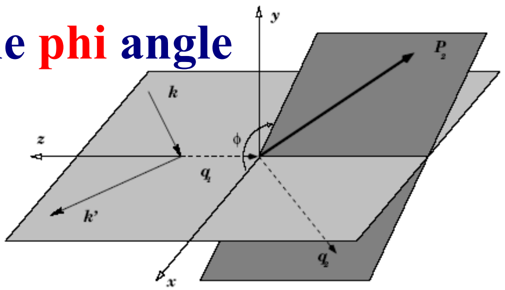
Beam charge-helicity asymmetry: ~ interacion term

|t|-slope: $e^{-b|t|} \Rightarrow \sigma_{DVCS} = |A_{DVCS}|^2 / 16\pi b$

The ratio between the real and imaginary parts of the DVCS amplitude can be extracted:

$$\rho = \frac{\mathrm{Re}\, A_{DVCS}}{\mathrm{Im}\, A_{DVCS}}$$

The phi angle



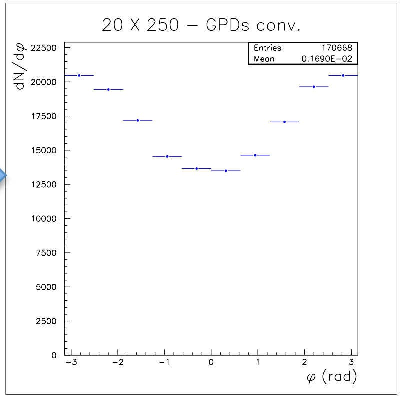
At EIC:

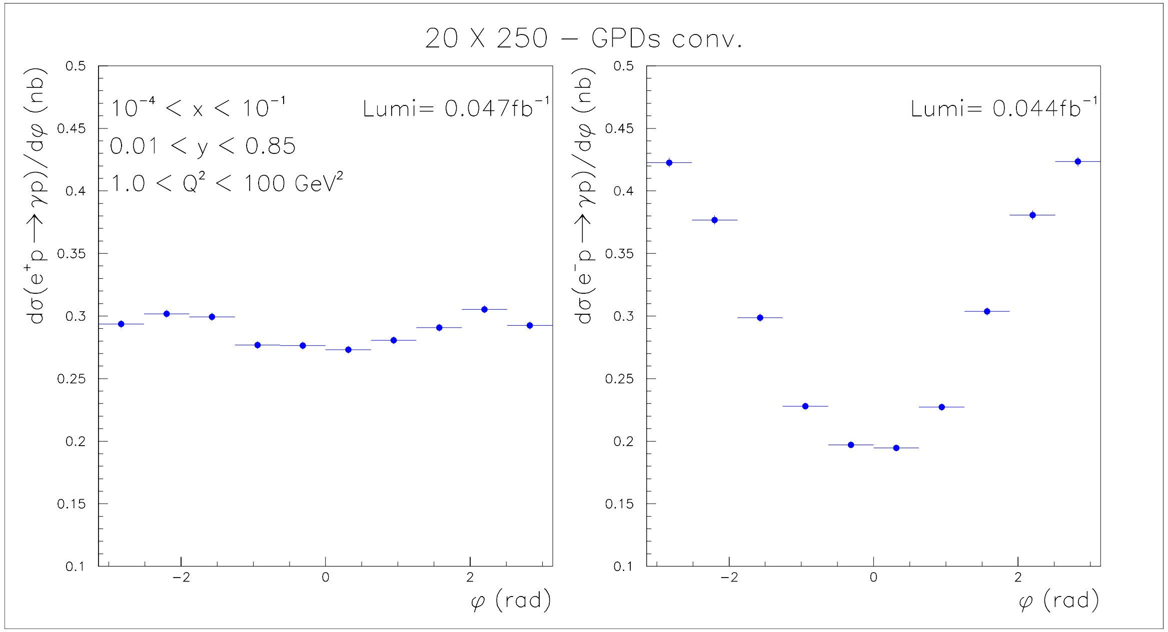
Possible with a positron beam, thanks to a good tracker coverage

Beam Charge Asymmetry

A data sample including DVCS + BH + Int has been generated for the configuration 20 X 250 for electrons and positrons beams separately

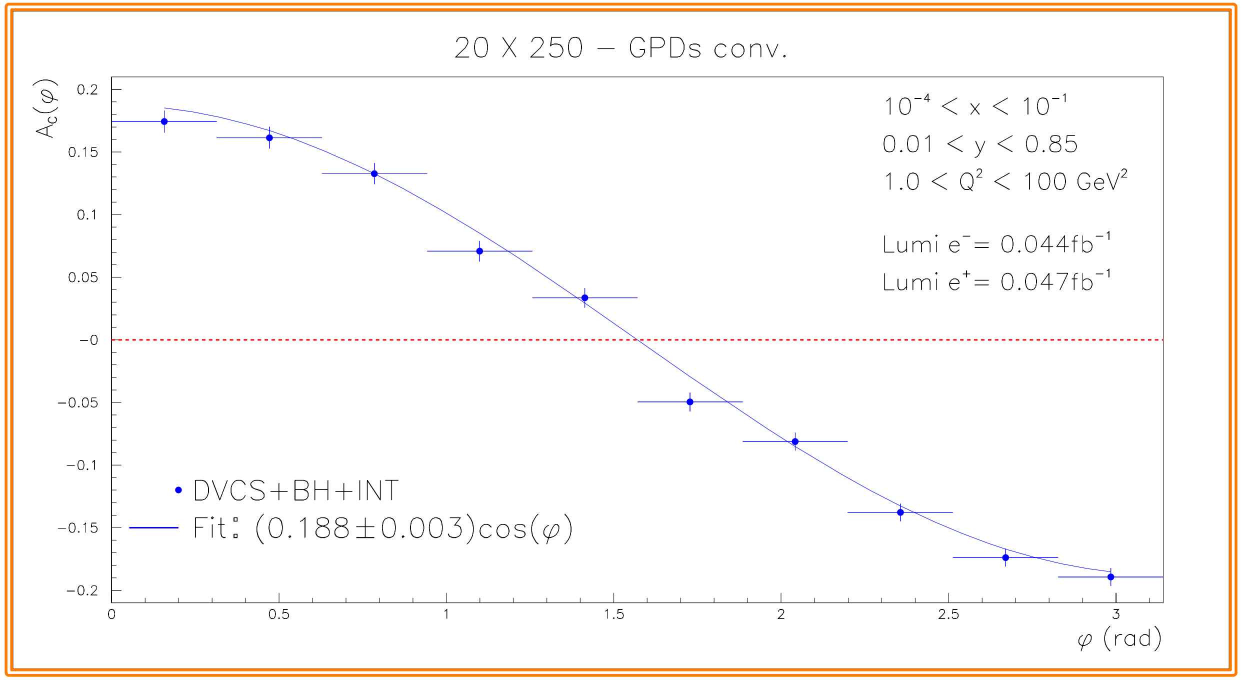
Lumi-ele: 44 pb^{-1}
Lumi-pos: 47 pb^{-1}

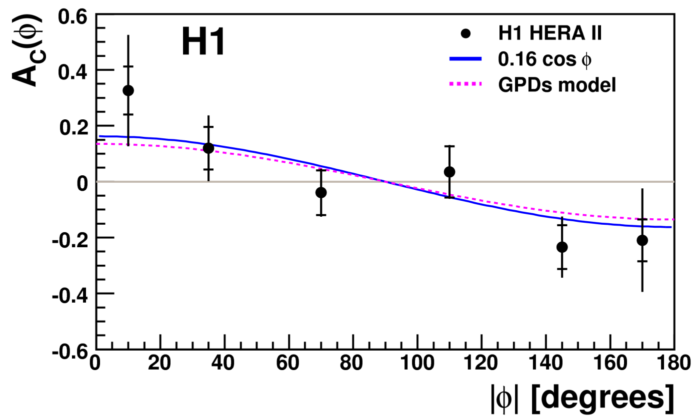


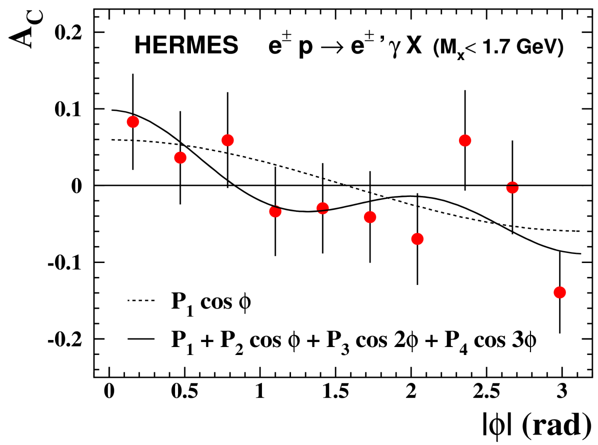


For both electrons and positrons the differential xsec vs ϕ has been extracted

Beam Charge Asymmetry



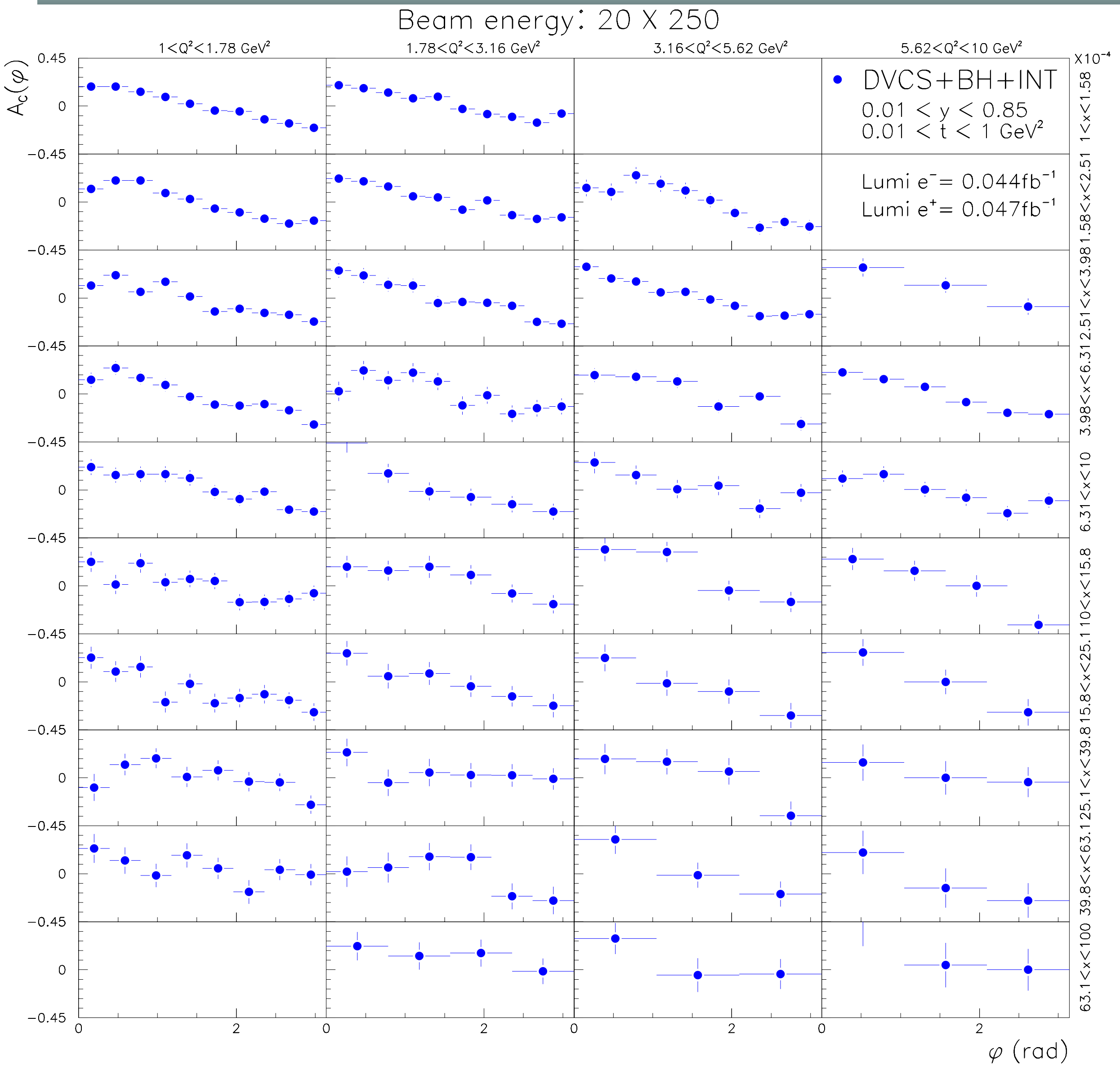




$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\mathrm{Re}\, A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

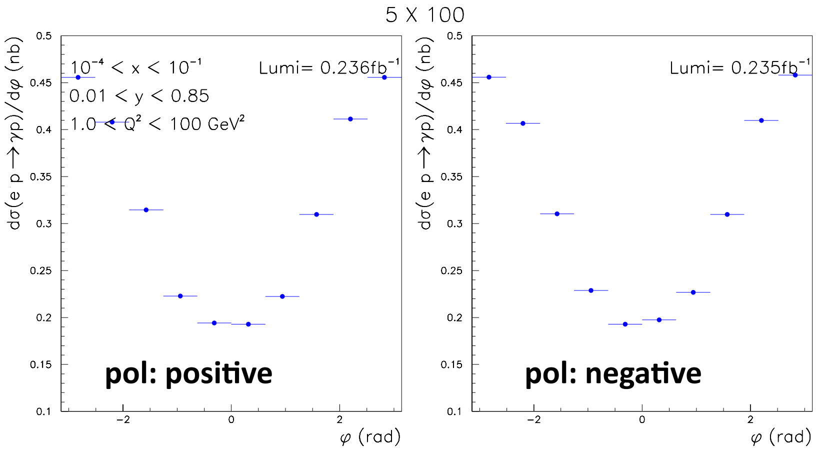
Excellent measurement with a modest beam-time. Accurate measurements in bins of Q^2 and x are possible! (Simulating more samples…)

Beam Charge Asymmetry



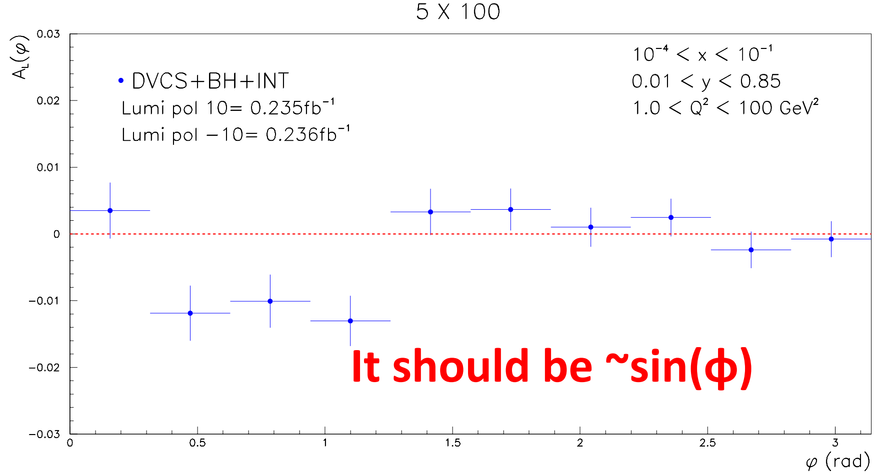
$10^{-4}<x<1.58x10^{-4}$
$1.58x10^{-4}<x<2.51x10^{-4}$
$2.51x10^{-4}<x<3.98x10^{-4}$
$3.98x10^{-4}<x<6.31x10^{-4}$
$6.31x10^{-4}<x<10^{-3}$
$10^{-3}<x<1.58x10^{-3}$
$1.58x10^{-3}<x<2.51x10^{-3}$
$2.51x10^{-3}<x<3.98x10^{-3}$
$3.98x10^{-3}<x<6.31x10^{-3}$
$6.31x10^{-3}<x<10^{-2}$

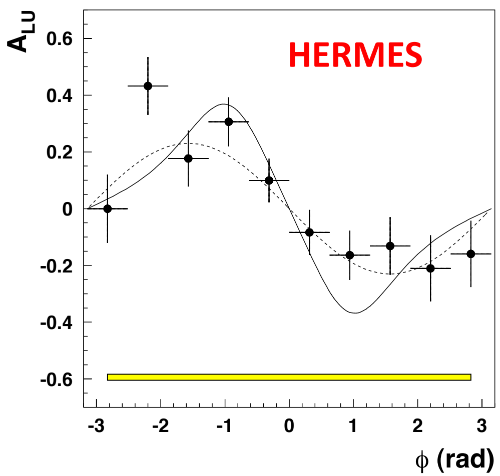
Longitudinal beam-helicity asymmetry



Pol. electrons: long. or anti-long.

Pol. protons: 0





Asymmetry appears much smaller than expected

Checking the MC code…

INT **DVCS**

$$A_{LU}(\varphi,e_l)=\frac{\frac{d\sigma^{\rightarrow}}{d|\phi|}-\frac{d\sigma^{\leftarrow}}{d|\phi|}}{\frac{d\sigma^{\rightarrow}}{d|\phi|}+\frac{d\sigma^{\leftarrow}}{d|\phi|}}=\frac{-e_\ell\frac{K_{\rm I}}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[\sum_{n=1}^{2}s_n^{\rm I}\sin(n\phi)\right]+\frac{1}{Q^2}s_1^{\rm DVCS}\sin\phi}{\frac{1}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left[K_{\rm BH}\sum_{n=0}^{2}c_n^{\rm BH}\cos(n\phi)-e_\ell K_{\rm I}\sum_{n=0}^{3}c_n^{\rm I}\cos(n\phi)\right]+\frac{1}{Q^2}\sum_{n=0}^{2}c_n^{\rm DVCS}\cos(n\phi)}$$

The INT term can be disentangled by the beam charge-spin asymmetry

Summary

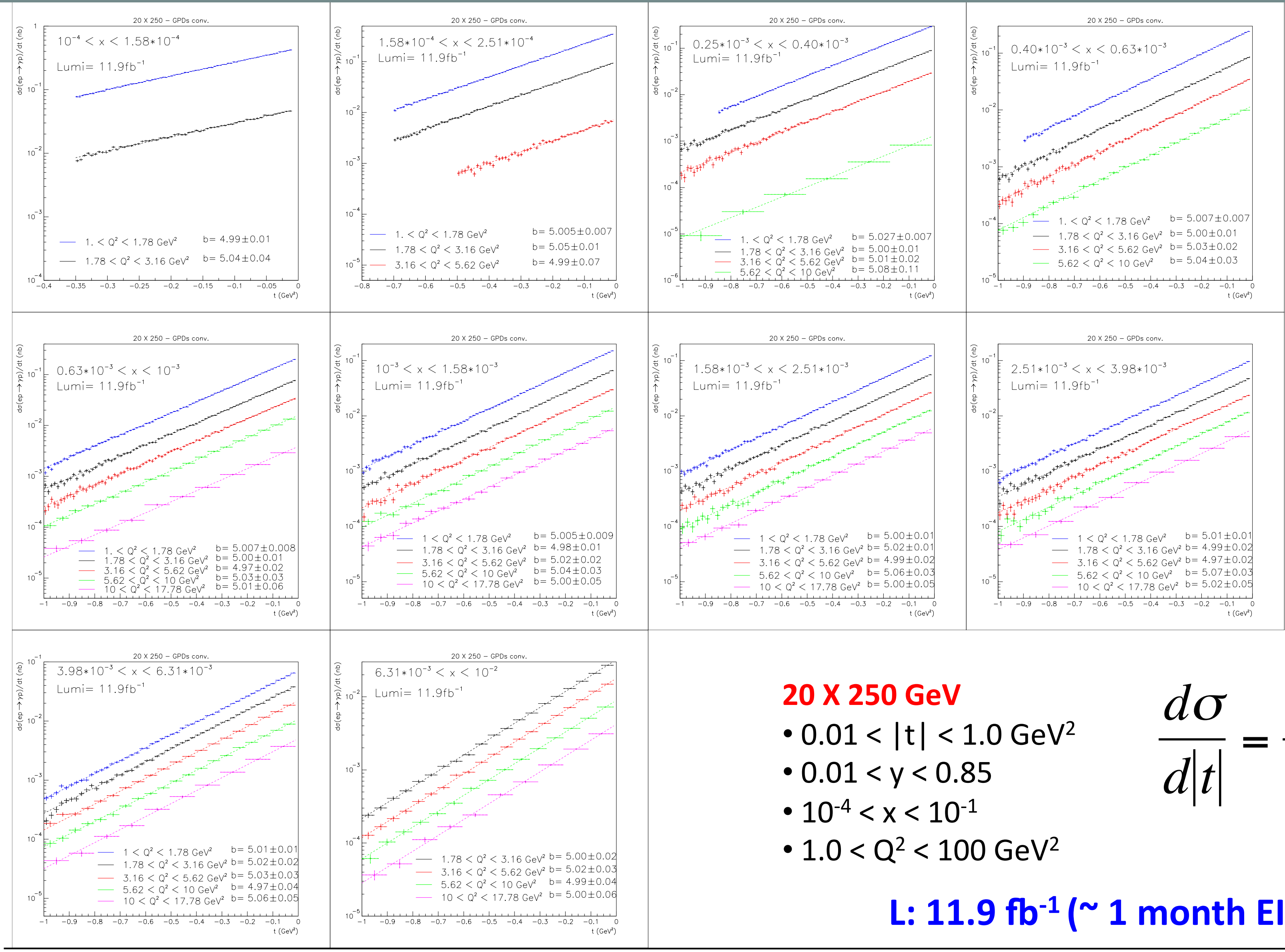
- Uncertainties for low |t| values will be dominated by systematics, the use of RP is convenient
- Differential xsec at large |t| values can also be measured with good accuracy, this requires years of data taking. The use of the main detector for measuring |t| from momentum conservation is the best option
- BCA can also be measured in bins of Q^2 and x, it is complementary to the |t| xsec, it required positron beam even with lower lumi

Outlook:

- Complete the energy scan
- Better Understand the implementation of the beam-helicity effects in the code
- Smear the distributions -> see Mike talk

Back up

|t|-differential x-sec: low |t|



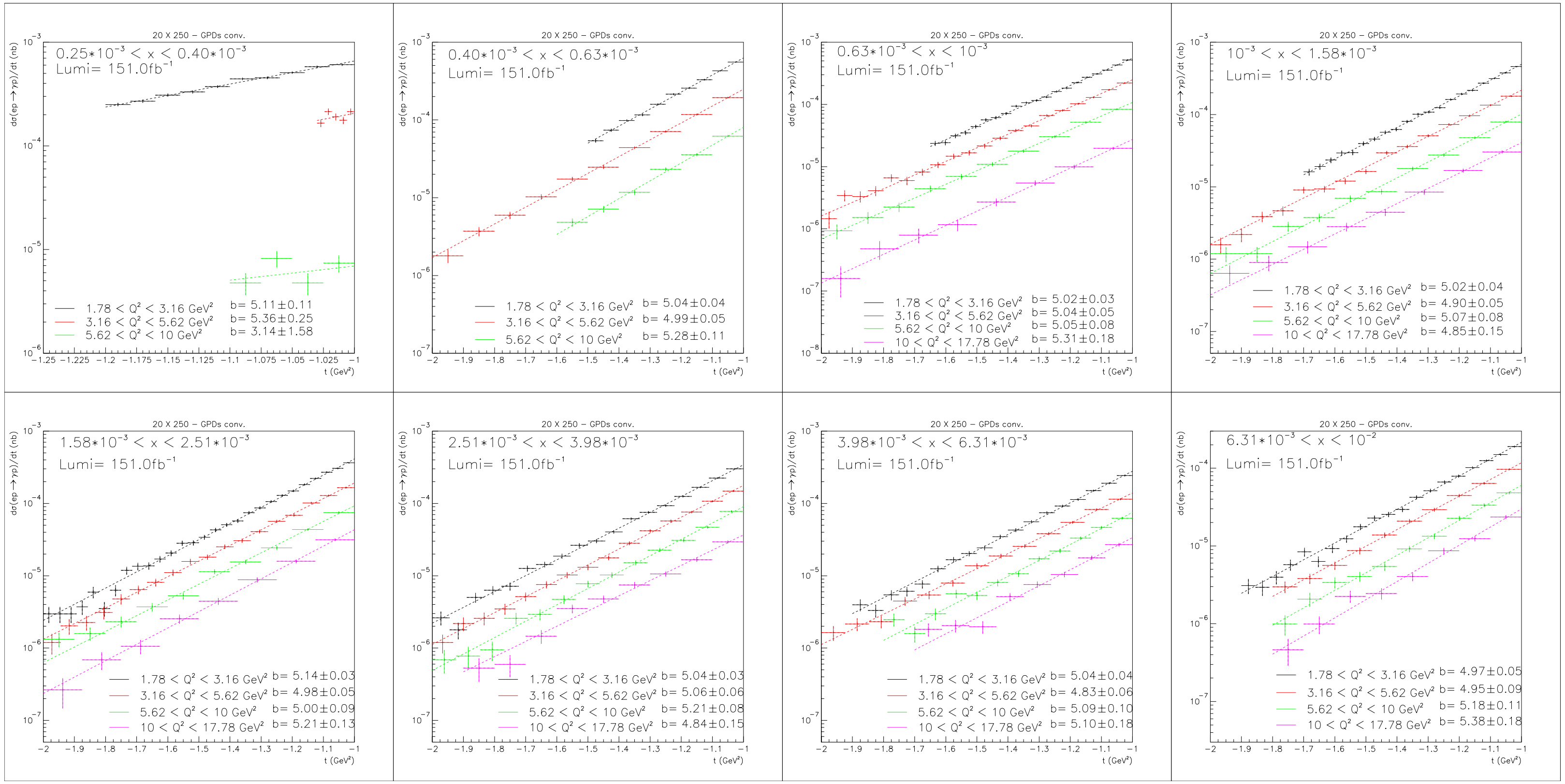
20 X 250 GeV

- $0.01 < |t| < 1.0$ GeV^2
- $0.01 < y < 0.85$
- $10^{-4} < x < 10^{-1}$
- $1.0 < Q^2 < 100$ GeV^2

$$\frac{d\sigma}{d|t|} = \frac{\#evt}{\Delta_{bin} \bullet \mathcal{L}}$$

L: 11.9 fb^{-1} (~ 1 month EIC)

|t|-differential cross section: high |t|



$1.0 < |t| < 2.0$ GeV^2

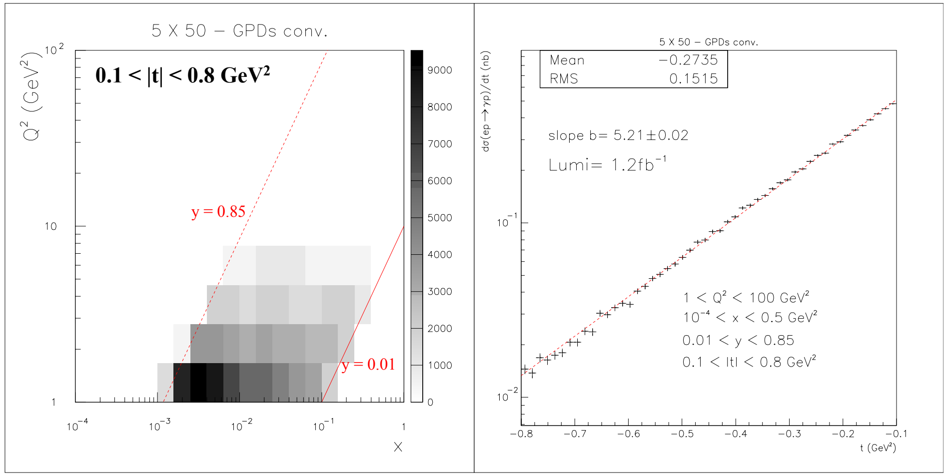
300k DVCS events simulated
L: 151 fb^{-1} (~ 52 weeks EIC)

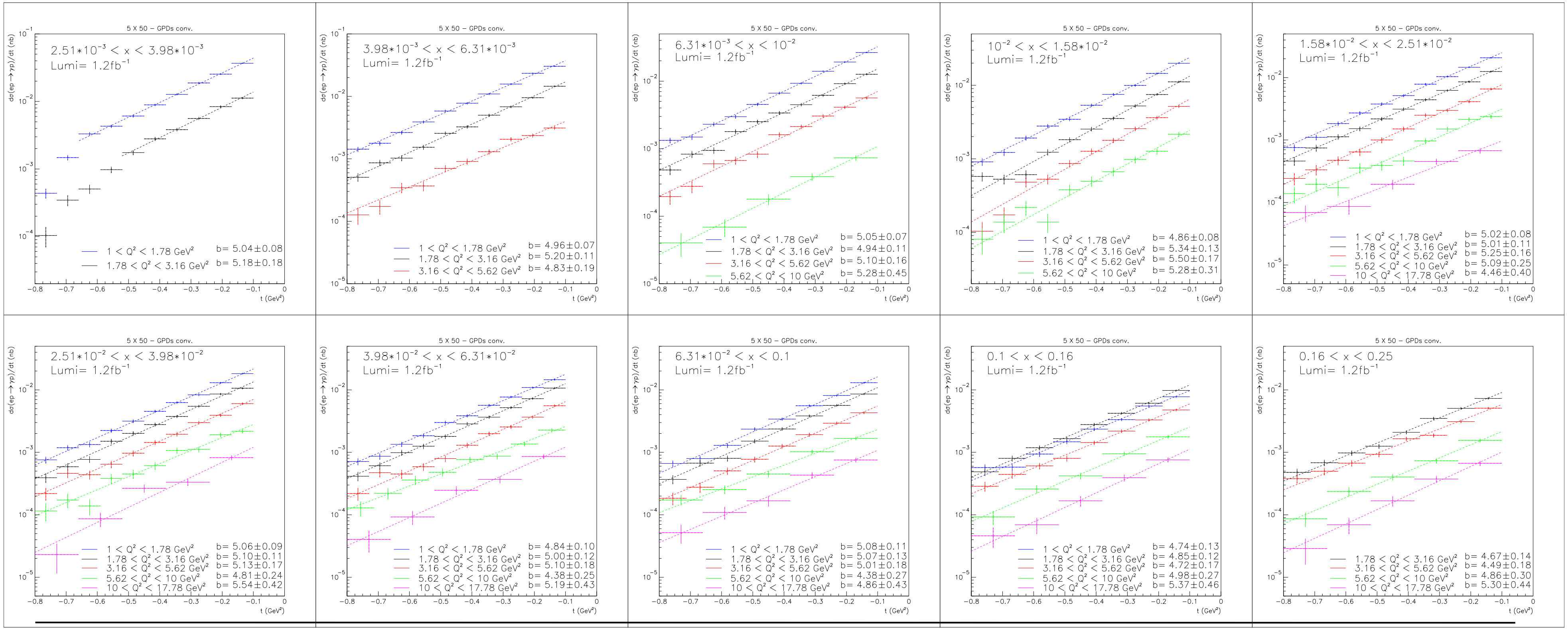
eRHIC can provide precise measurement of the |t|-slope even at large |t| values… but this may require years of data taking

5 X 50

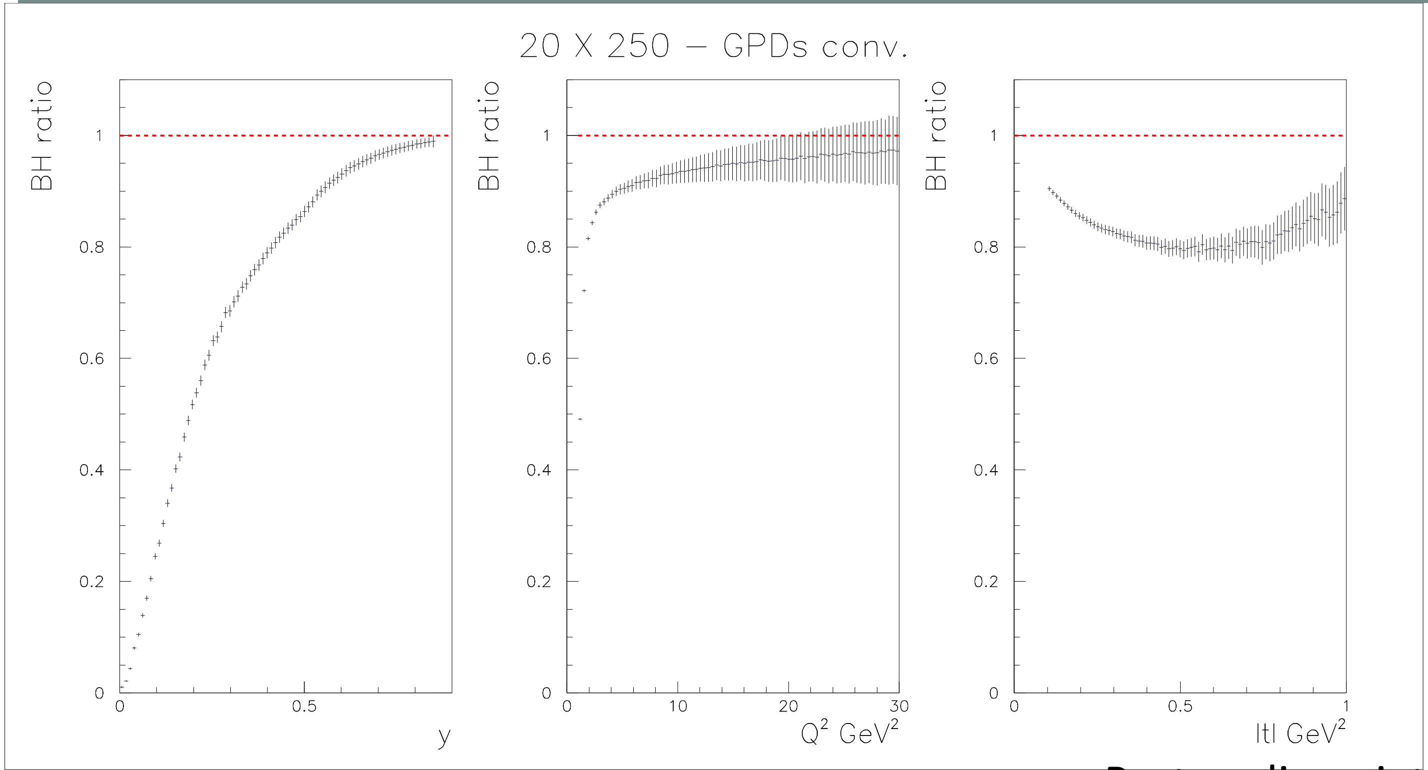
Lumi: 1.2 fb^{-1} (~ 1 week EIC)

$$\frac{d\sigma}{d|t|} = \frac{\#\,evt}{\Delta_{bin} \bullet \mathcal{L}}$$





Fraction of Bethe-Heitler



1.0 < Q^2 < 100 GeV^2
0.01 < y < 0.85
0.1 < |t| < 1.0 GeV^2

DVCS and BH samples normalized at Lumi

$$frac(BH) = \frac{BH_{evt}}{BH_{evt} + DVCS_{evt}}$$

BH generated sample much smaller than DVCS one -> error bars

- Proton dissociation not included for both DVCS and BH (but mostly process independent…)
- BH dominates at large y (as expected!)
- Part of BH will be removed by DVCS selection criteria for a DVCS enhanced sample (interference term not affected)